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Space Internet Technology

6	Space Internet Overview
6A	Networking Simulation & Emulation
6B	Space Internet Router
6C	Network Module
6D	RF Communications Module
6E	Integrated Space Internet Demos

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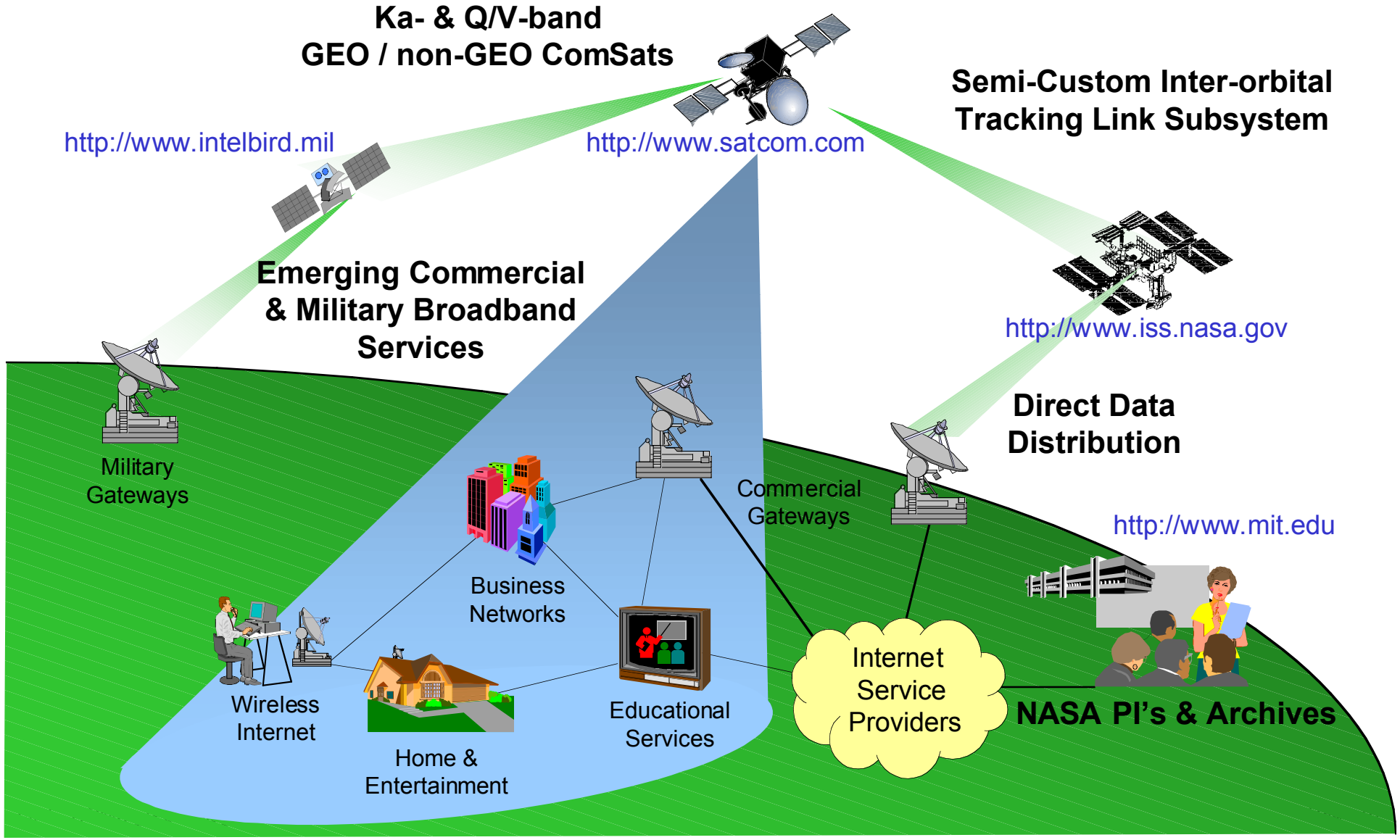
Space Internet Vision

Space Assets as Elements of the Internet



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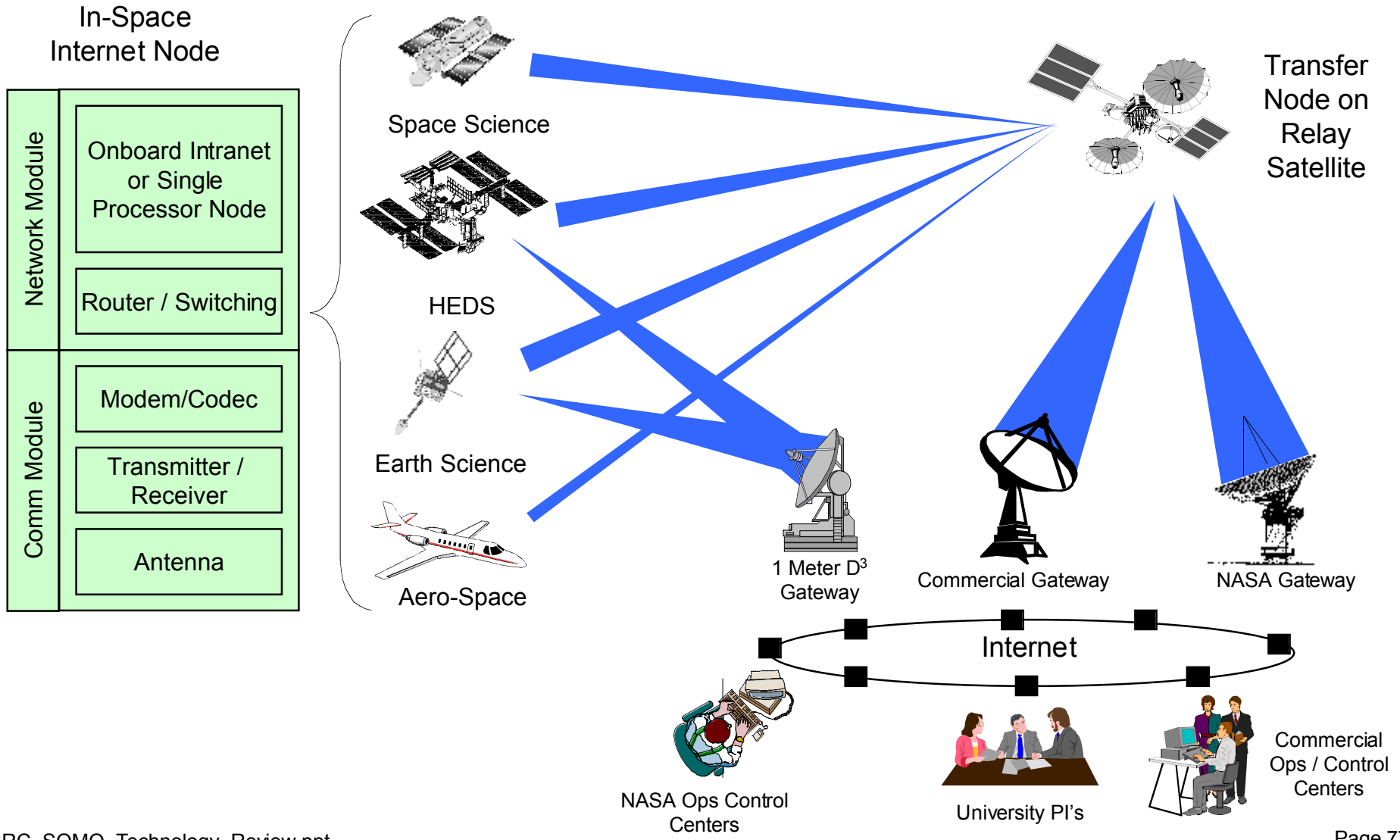
Space Internet Architecture



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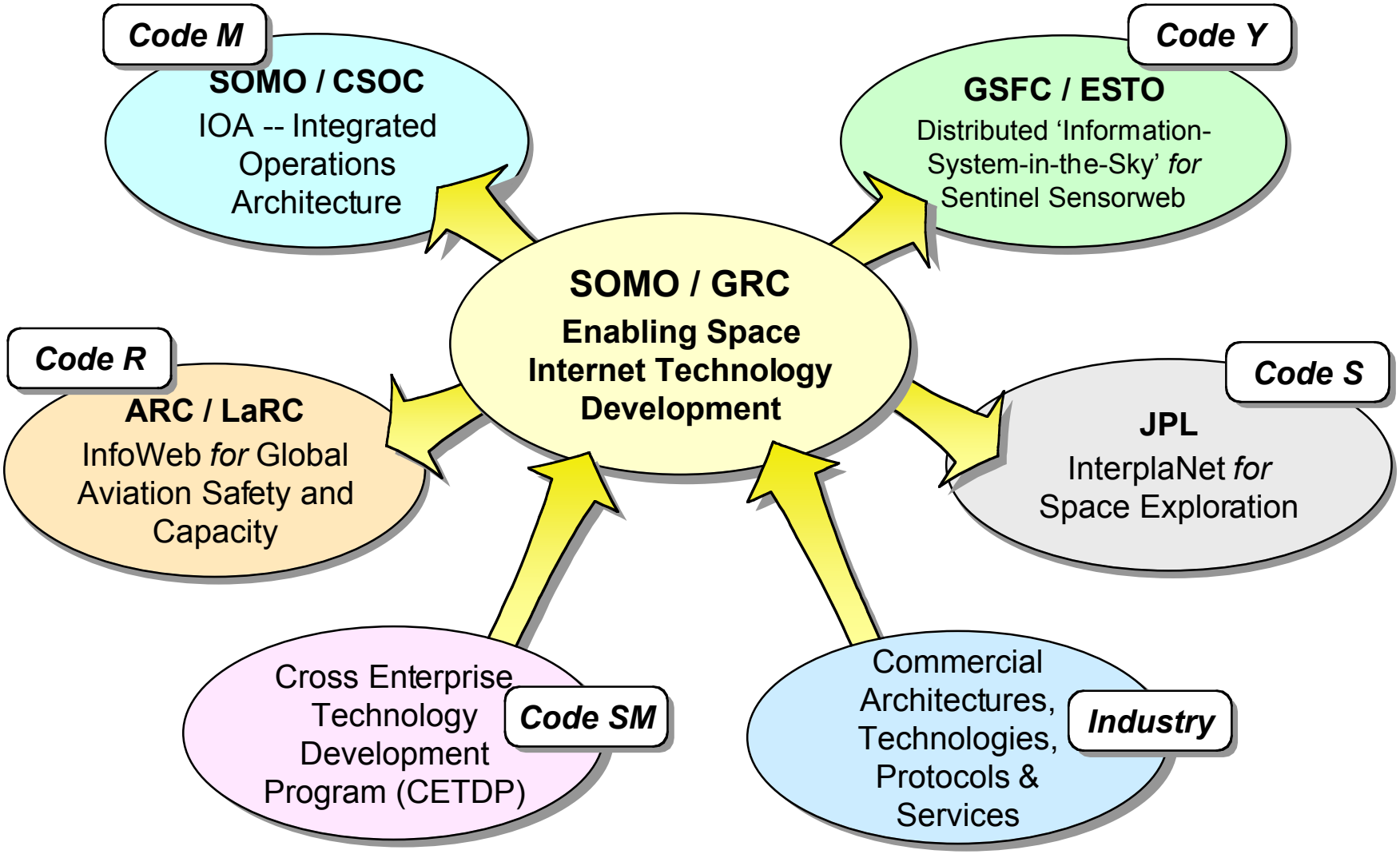
Space Internet Technology Insertion



6A Networking Simulation & Emulation

Michael J. Zernic

Glenn Research Center

Networking Simulation & Emulation

Center:	GRC	**POC:**	Mike Zernic	**Date:**	3/25/1999
Funding Enterprise:	Code M/SOMO	**Phone:**	216.433.5286	**NTIDB Record #:**	1885, 1886, 1888, 9462
UPN-5:	TBD, 632-50	**email:**	mzernic@grc.nasa.gov	**Tech Prog Element #:**	6A

DESCRIPTION: **Current TRL:** 3 **Planned TRL:** 6

- Validate space internet concepts, protocol implementation schemes,technologies and tools by:
  - utilizing a laboratory networking simulation and emulation capability characterizing dynamic environment and operational H/W & S/W
  - performing networking experiments over TDRSS and commercial communication architectures
  - developing and providing models and tools for mission operations implementation
- GRC to be co-investigator w/LMSOC to develop and conduct validation experiments utilizing TDRS and commercial architectures

JUSTIFICATION:

- This capability and approach is critical as a transition from and to build upon the technology and standards foundation laid by the ACTS networking experiments (ACTS EOL Q4FY00)
- The IOA will mature from these contributions by which GRC will investigate the fundamentals of the space internet issues and supply products to the CSOC Technology Assessment and Integration Center for evaluation applicable to the IOA implementation and cost reduction objectives

RESOURCES ($K):

	FY98	FY99	FY00	FY01	FY02	FY03
Guideline			310	615	730	730

MILESTONES:

- Q1FY00 Develop options to experiment over TDRSS
- Q3FY00 Finalize laboratory simulation/emulation capability
- Q4FY00 Establish Lab-based benchmarks
- Q2FY01 Complete initial TDRSS trials
- Q4FY01 Develop options to validate over commercial
- Q4FY02 Complete initial commercial trials
- Q2FY03 Deliver initial protocol implementation models & network simulation/emulation products for use in generic IMOC implementations
- Q3FY03 Initial IP compliant commercial satcom Q4FY03 Migrate space internet technology on-board spacecraft(s)

STATUS:

- Some lab capability exists (Code SM) augmentation needed to better reflect IOA concepts, performance expectations, &objectives
- ACTS networking experiments have begun to address network interoperability, but ACTS EOL is Q4FY00
- A preliminary TDRSS concept has surfaced via a NRL interest

Networking Simulation & Emulation

CUSTOMER(S):

- SOMO: address IOA technology gaps and standards issues post-ACTS via a combination lab-TDRSS-commercial approach
- Other NASA Enterprises: achievement of space internet enables enhanced data and mission services as well as promotes NASA's transition to commercial assets mandate

MISSION RELEVANCE:

- SOMO/IOA: achieve IOA objectives and milestones
- STS, ISS, and near-Earth missions: enhanced data/mission services directly to the user and among users
- Space science missions: Internet enabled Planet LAN networks

MAPPING TO STRATEGIC ROADMAP:

Pillar 1: Reduce Cost of NASA Space Operations	1. Commercial Utilization	X	**Pillar 2:** Provide enabling data services to Enterprises	1. High Performance Comm	
	2. Network Interoperability	X		2. Intelligent Syst & Autonomy	
	3. System Automation			3. Innovative Info Syst	X
	4. Process Tools			4. Environm Characterization	

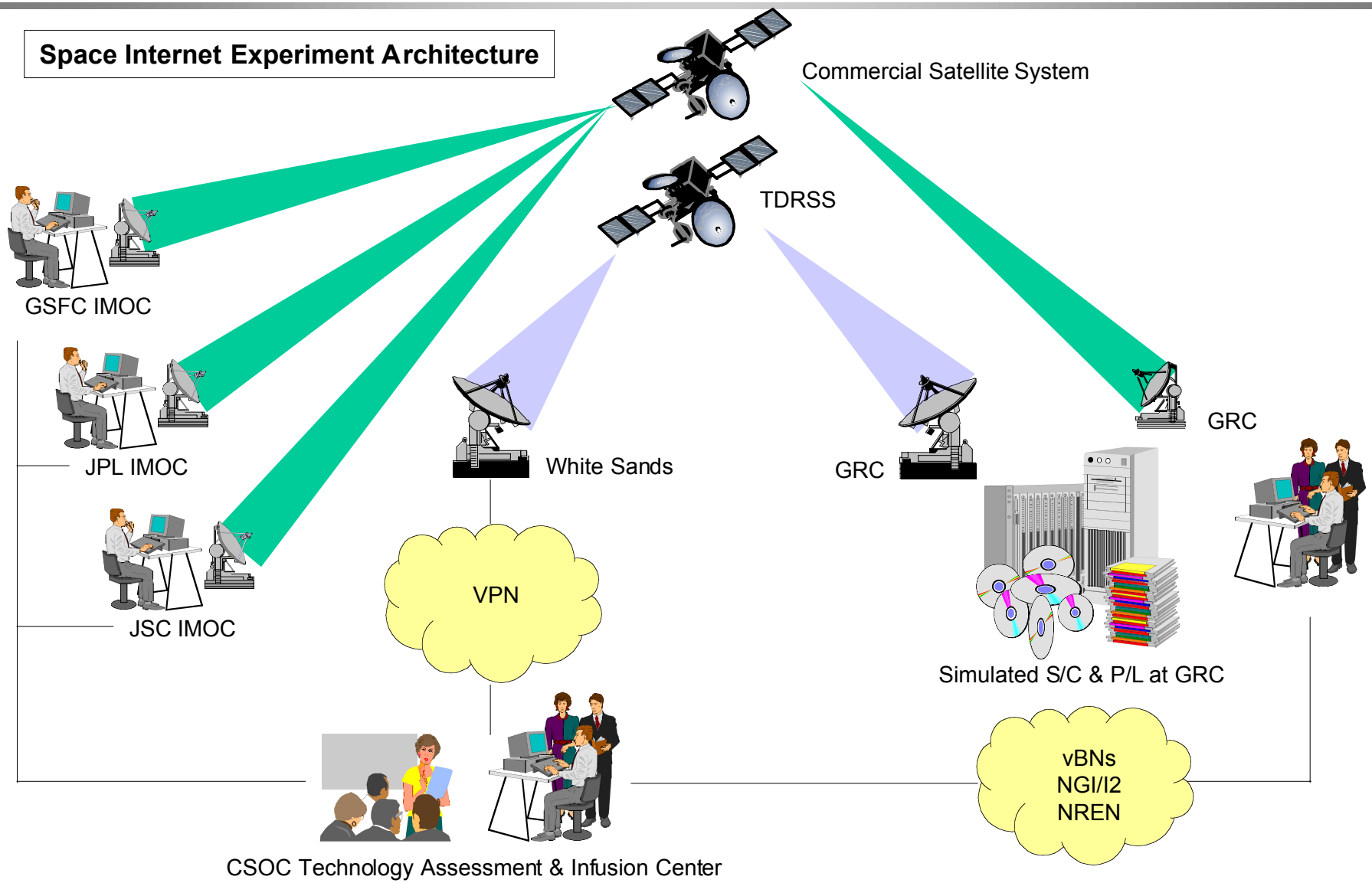
INTER-RELATIONSHIPS:

- Leverage CETDP funded lower TRL satcom network technology development(GRC) with SOMO funded technology at GSFC
- Other Enterprises fund the missions that will reap the benefits of enhanced data/mission services
- Other government organization (e.g., AFRL, NRL) evaluate advanced satcom architectures, corresponding technologies, and transition to commercial assets

IMPACT OF CANCELLATION or DELAY :

- Capability lost to emulate environment for validation of space internet implementation
- Leverage & momentum lost from ACTS network experiments impacting NASA missions
- Customers negatively impacted by jeopardizing the schedules and effectiveness of IOA implementation, spacecraft/instruments nodes on the internet, and the Agency's transition to commercial assets
- Delays evaluation of proprietary/point solutions vs. COTS equipment/service availability
- Other programs: Loss of contributions to customers and leveraged inter-relationships

Networking Simulation & Emulation



6B Space Internet Router

Phillip E. Paulsen

Glenn Research Center

Space Internet Router

Center: GRC
Funding Enterprise: Code M / SOMO
UPN-5: TBD, 632-50

POC: P. Paulsen
Phone: 216.433.6507
email: phillip.e.paulsen@grc.nasa.gov
Current TRL: 4

Date: 3/25/1999
NTIDB Record #: 1885, 1888
Tech Prog Element #: 6B
Planned TRL: 6

DESCRIPTION:

- Development of a Space Internet Router
  - Miniaturization / packaging / interface definition, design, and development
  - Radiation hardening
  - Qualification for space

JUS1TIFICATION:

- The development of a space qualified router (which currently does not exist) will enable NASA's space assets to act as a "Node on the Internet"
- Space qualified routers are an essential part of the proposed IOA architecture (which assumes that they will be developed)
- Once operational, space qualified routers will enable researchers to remotely access and control their space-based experiments, eliminating the "Person in the Loop" currently needed to physically connect experiments and communication systems

RESOURCES ($K):

	FY98	FY99	FY00	FY01	FY02	FY03
Required	N/A	N/A	125	925	610	610

MILESTONES:

- Q1 FY00 - Authority to proceed, modification of existing CISCO MOU, interface / packaging definition, design, & development
- Q4 FY01 - Component radiation hardness testing complete
- Q4 FY03 - Complete (ready for flight testing)

STATUS:

- NASA GRC has had a Space Act Agreement in place with CISCO (a major router vendor) for approximately 2 years
  - Performed ground based simulation and beta testing of next generation high rate routers using the ACTS satellite
- GRC has had an extensive dialog with CISCO concerning the potential use of their products in future NASA satellites
  - GSFC & CSOC were also included during the last session to help with concept / requirement definition

Space Internet Router

CUSTOMER(S):

- Once the IOA has been fully implemented, it is anticipated that all NASA missions will be required to use a space qualified router for access and control of their experiments. GRC has been in communication with members from each of the following NASA Enterprises to ensure that their requirements are fully understood and incorporated in the final design of router products:
- Space Science
  - Mission to Planet Earth
  - Human Exploration and Development of Space
  - Aeronautics and Space Transportation Technology

MISSION RELEVANCE:

- Once fully implemented, the IOA will fundamentally change the way that NASA mission operations is conducted. It is anticipated that the following SOMO customers will be affected first:
  - STS
  - ISS
  - GSFC small missions (SMEX) & the earth observing missions

MAPPING TO STRATEGIC ROADMAP:

Pillar 1: Reduce Cost of NASA Space Operations	1. Commercial Utilization	X	**Pillar 2:** Provide enabling data services to Enterprises	1. High Performance Comm	X
	2. Network Interoperability	X		2. Intelligent Syst & Autonomy	X
	3. System Automation			3. Innovative Info Syst	X
	4. Process Tools			4. Environm Characterization	

INTER-RELATIONSHIPS:

- Code SM is currently funding the development of protocols for use in a space-based internet
- NASA GRC has recently entered into a MOU with Sandia Labs for equipment radiation hardness testing and collaboration
- NASA GRC has a Space Act Agreement in place with CISCO to conduct beta testing of advanced router products using ACTS

IMPACT OF CANCELLATION or DELAY :

- The IOA as written can never be fully implemented without space qualified routers

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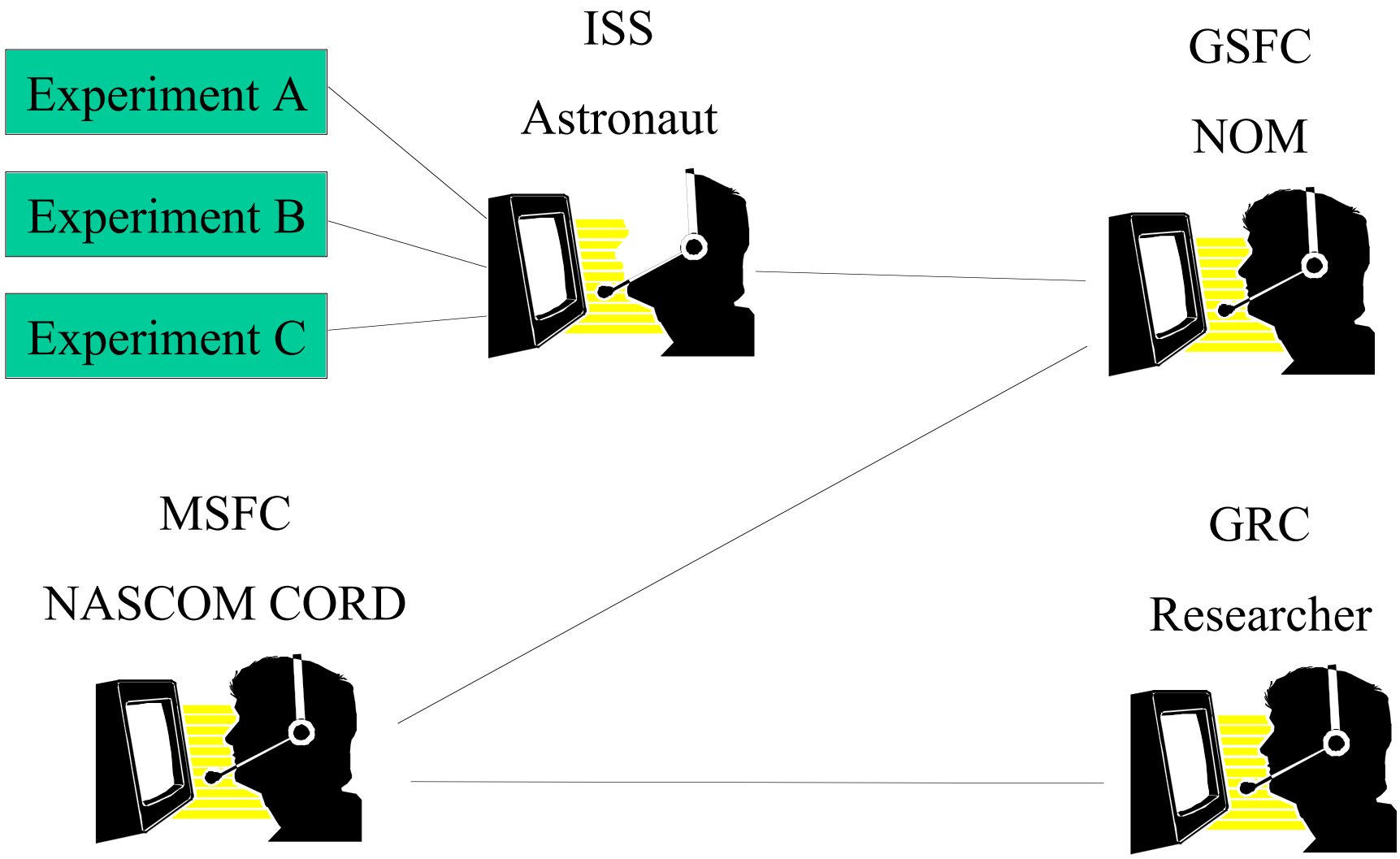
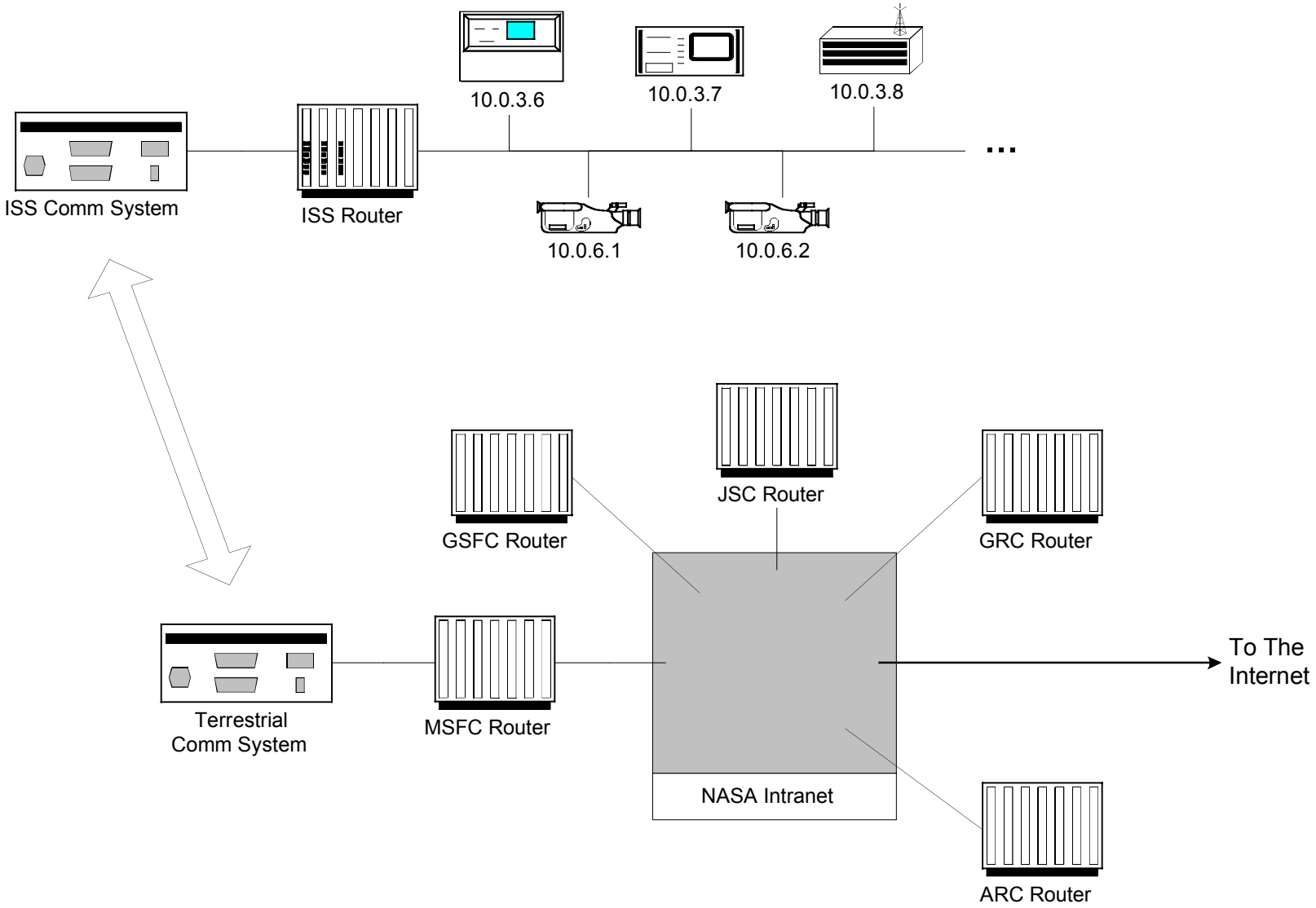
Current System Routing



Space Internet Routing



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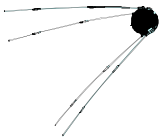
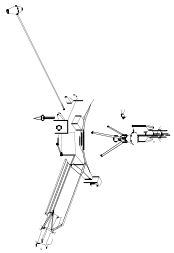
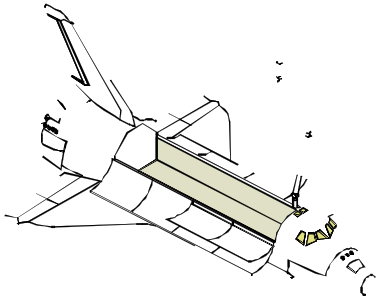
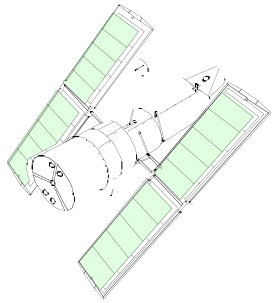
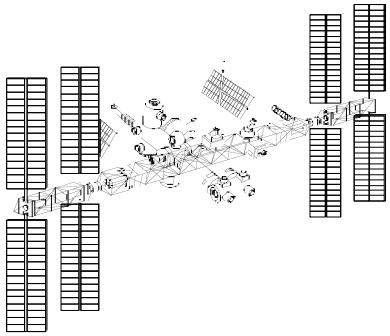
Space Internet Mission Classes







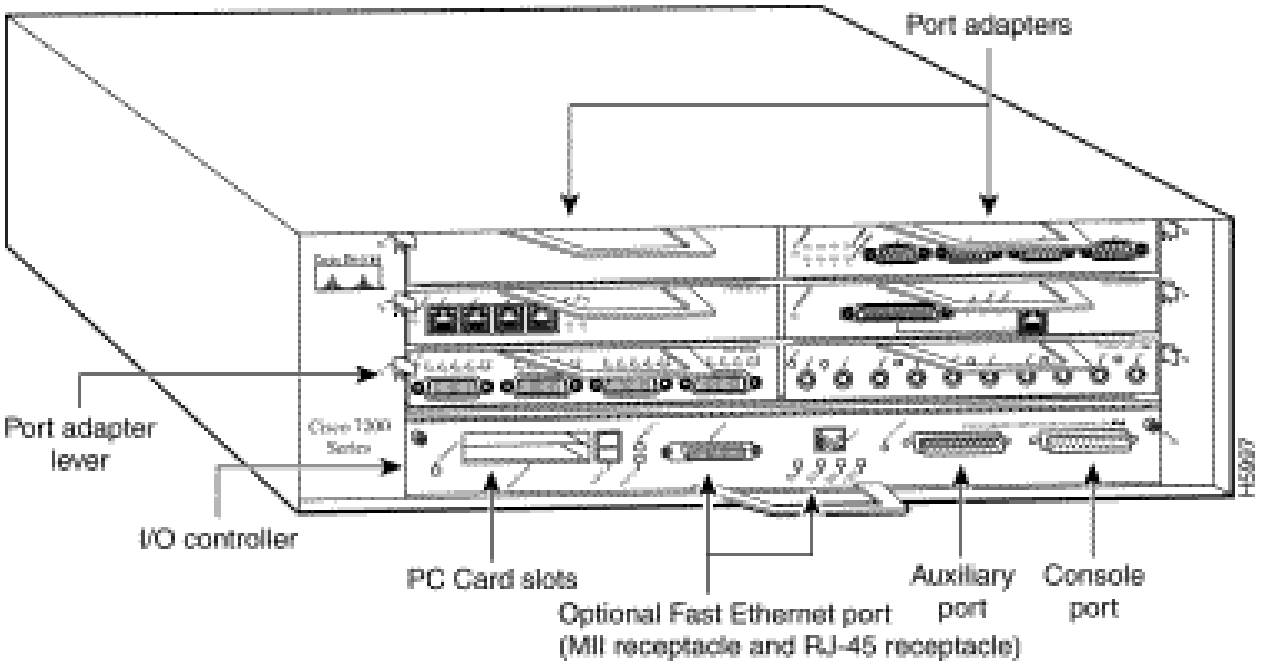




Small	Intermediate	Large	Extra Large
<45 Mbps	45 Mbps	155 Mbps	622 Mbps
ROAC	CISCO 3600	CISCO 7200	CISCO 12000

CISCO 7200 Series High Performance Router

Current (rack mounted) configuration



6C Network Module

Gene Fujikawa

Glenn Research Center

Network Module

Center:	GRC	**POC:**	G. Fujikawa	**Date:**	3/30/1999
Funding Enterprise:	Code M/SOMO	**Phone:**	216.433.3495	**NTIDB Record #:**	1883
UPN-5:	TBD, 632-50	**email:**	g.fujikawa@grc.nasa.gov	**Tech Prog Element #:**	6C

DESCRIPTION: **Current TRL:** 3 **Planned TRL:** 6

- The Network Module provides the necessary interface (both hardware and firmware) between the various elements of the spacecraft (instruments, routers, data storage, CPUs), and the Communications Module (modem, RF transmit/receive equipment).
- Integrated functions within the Network Module include: IP/Ethernet/ATM interface, protocol encoding/decoding, clock and timing, encryption/decryption, health status of link (both operational and QoS).
- Multiple versions could be developed depending on data rates and nature of services (e.g. ATM and non-ATM version).

JUSTIFICATION:

- To realize the Integrated Operations Architecture, all spacecraft instruments and subsystems will eventually be connected to the network. In order to leverage the significant commercial communications satellite infrastructure anticipated to be in place in the near future, NASA spacecraft must appear to these systems as typical customers (i.e. cellular telephone users, low and high data rate users, etc.). The module developed under this task will enable the functionality required to bridge that gap.

RESOURCES ($K):

	FY98	FY99	FY00	FY01	FY02	FY03
Guideline			130	485	855	970

MILESTONES:

- FY00 - Complete a proof-of-concept demonstration unit
- FY01 - Demonstrate performance in IP testbed
- FY02 - Complete baseline protoflight network module
- FY03 - Perform flight demonstrations and experiments beginning in FY03.

STATUS:

- HS-VSAT network module demonstrated through ACTS in FY99 increasing user data rate from 1.544 Mbps (T1) to 24 Mbps.
- Internet protocol stacks and switching protocols are being evaluated for NASA mission implementation.

Network Module

CUSTOMER(S):

- HEDS - helps fill specific communications technology gaps identified for the CSOC IOA, and helps enable telescience and telepresence for ISS users
- Earth Science - provides a solution for enabling the “Sentinal Sensorweb” and the “Distributed Information System-in-the-Sky”
- Space Science - supports near-Earth science spacecraft data return via commercial assets

MISSION RELEVANCE:

- Provides communications solution for several mission scenarios since the communications modules enables NASA mission spacecraft to leverage the commercial infrastructure available during the duration of the mission. The Space Internet strategy, of which the communications module is a critical element, seeks to reduce NASA missions operations costs by enabling NASA spacecraft to be customers of commercially provided communications.

MAPPING TO STRATEGIC ROADMAP:

Pillar 1: Reduce Cost of NASA Space Operations	1. Commercial Utilization	X	**Pillar 2:** Provide enabling data services to Enterprises	1. High Performance Comm	X
	2. Network Interoperability	X		2. Intelligent Syst & Autonomy	
	3. System Automation			3. Innovative Info Syst	X
	4. Process Tools			4. Environm Characterization	

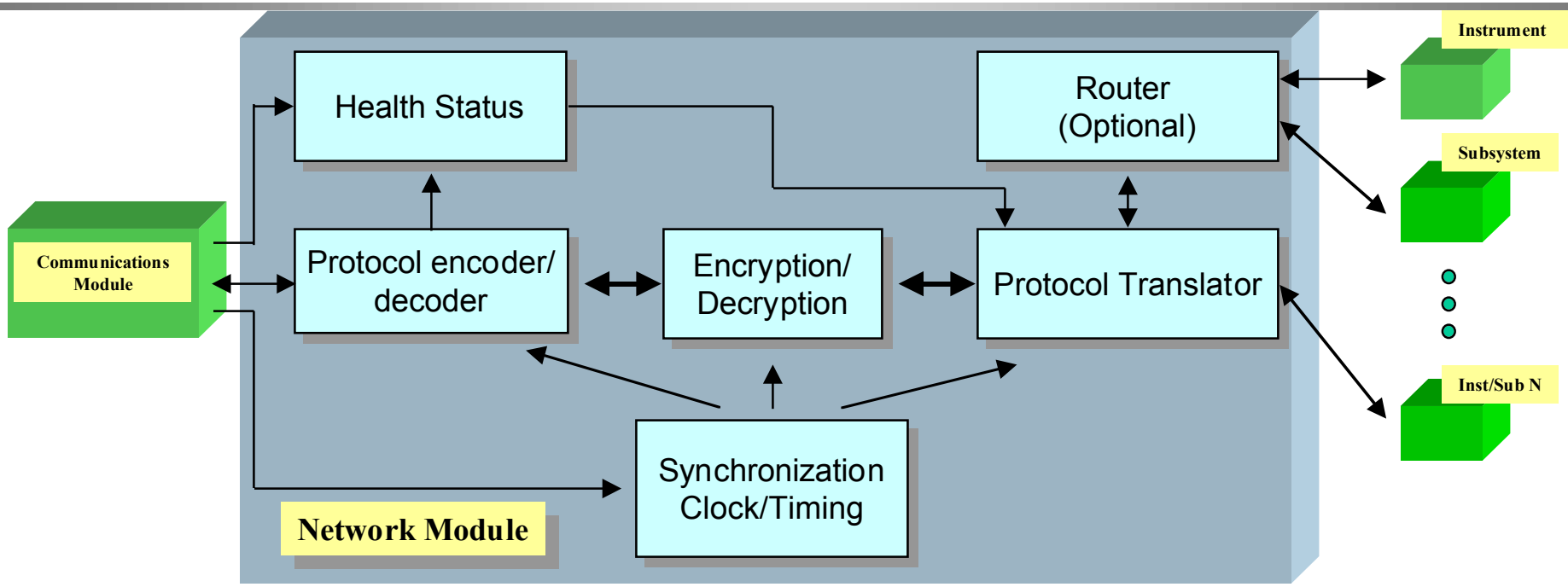
INTER-RELATIONSHIPS:

- Previous and currently funded investments by Code SM (now CETDP) include: Simulations of TCP/IP and ATM over hybrid satellite/terrestrial links, ATM interface for the ACTS High Speed VSAT, ATM Over Satellite NRA w/ COMSAT (led way to Linkway 2000 terminal), SBIR on ATM cell-loss protection (Consultare), SiGe fast packet switch (Sierra Monolithics). Investments in future technologies will result from teaming arrangements with SOMO, CETDP, various NASA Enterprise mission offices, and commercial industry.

IMPACT OF CANCELLATION or DELAY :

- This is a new technology proposal to help realize the vision presented in the Integrated Operations Architecture. NASA needs to invest in those critical, enabling technologies which will allow spacecraft to function as nodes within the Intranet/Internet. Without funding these gap-filling technologies, NASA will continue to provide costly point solutions for its communications.

Network Module



Health Status
Monitor link performance and determine quality of service for link status notification available to spacecraft data systems and for use in adaptive error mitigation control.

Encryption/Decryption
Provide selectable encryption and decryption services for secure data and control communication.

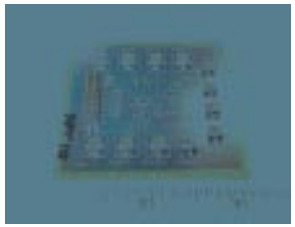
Protocol Encoder/Decoder
Provide selectable error protection to critical header and control data specific to chosen protocol.

Synchronization
Provides system timing and synchronization with communication module timing.

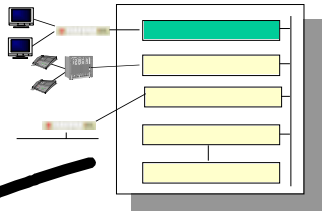
Protocol Translator
Protocol conversion processing and formatter (IP, Ethernet, ATM, etc.) including necessary buffering and control to convert desired protocol data for serial data transmission.

Router (Optional)
Provide multiple access from instruments, data handling and control systems, and various subsystems throughout the spacecraft. Optional within network module, depending on chosen protocol and system architecture.

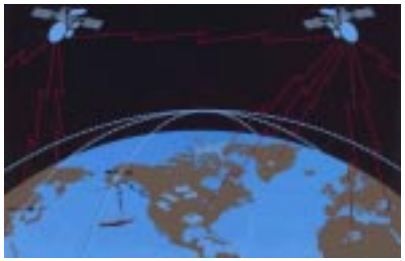
Network Module



SiGe Fast Packet Switch (Sierra Monolithics)

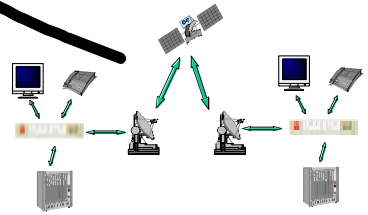


Satellite-Based, Low Rate ATM Network (COMSAT)

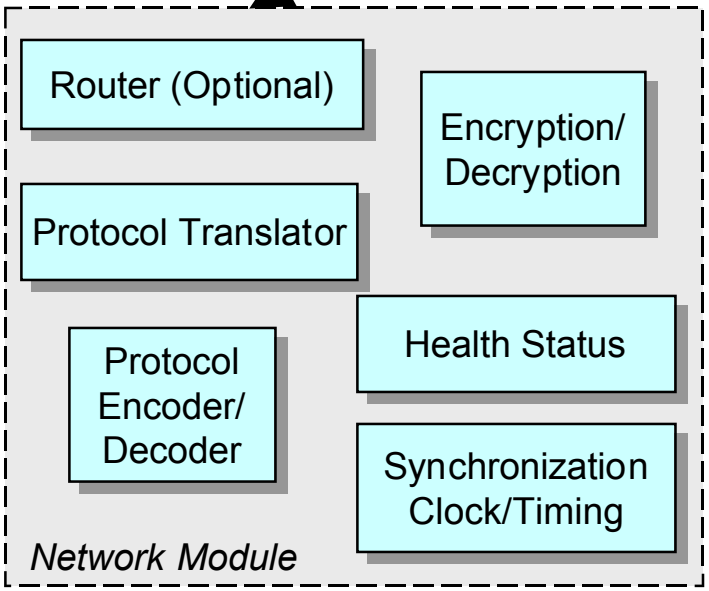


Satellite network architectures, Internet protocols, testbeds

ATM Multimedia error correcting codes (Consultare)



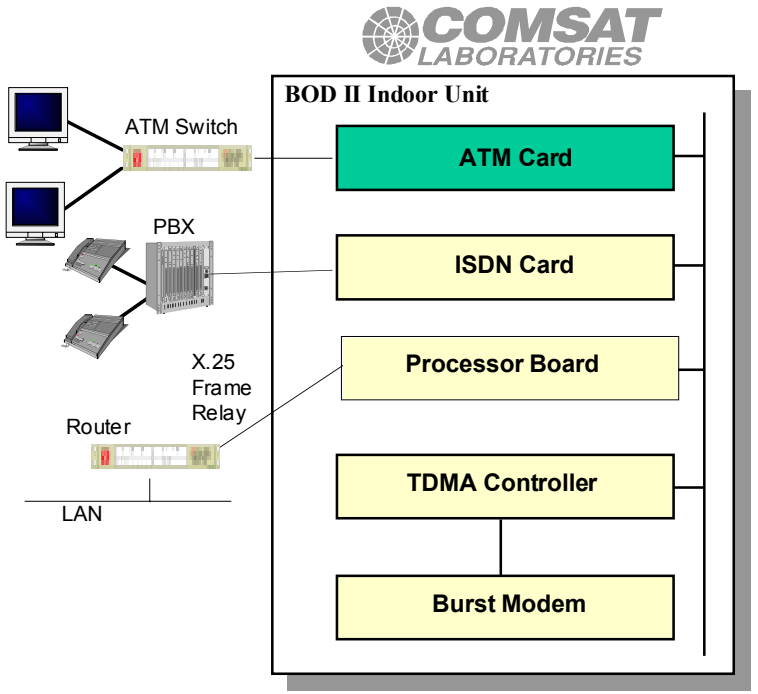
ACTS HSVSAT Demo



Previous investments by GRC in key technologies supports the vision of the IOA and help realize the goal of spacecraft as nodes on the Intranet/Internet

Satellite-Based Low Rate ATM Network

- Develop low rate, ATM network interface for COMSAT bandwidth-on-demand (BOD II) terminal, supporting ISDN and X.25 services
- Full mesh, single hop connectivity among multiple sites
- Automatic, adaptive bandwidth-on-demand using small, low cost terminals
- Effective congestion control
- Led to development of Linkway-2000 product for fixed 2.5 Mbps carrier rates with ISDN, SS7, ATM, and frame relay interfaces
- 50% cost shared NRA by NASA GRC and COMSAT Labs



Produced first ATM bandwidth-on-demand TDMA system and demonstrated seamless interoperability between terrestrial and satellite ATM networks

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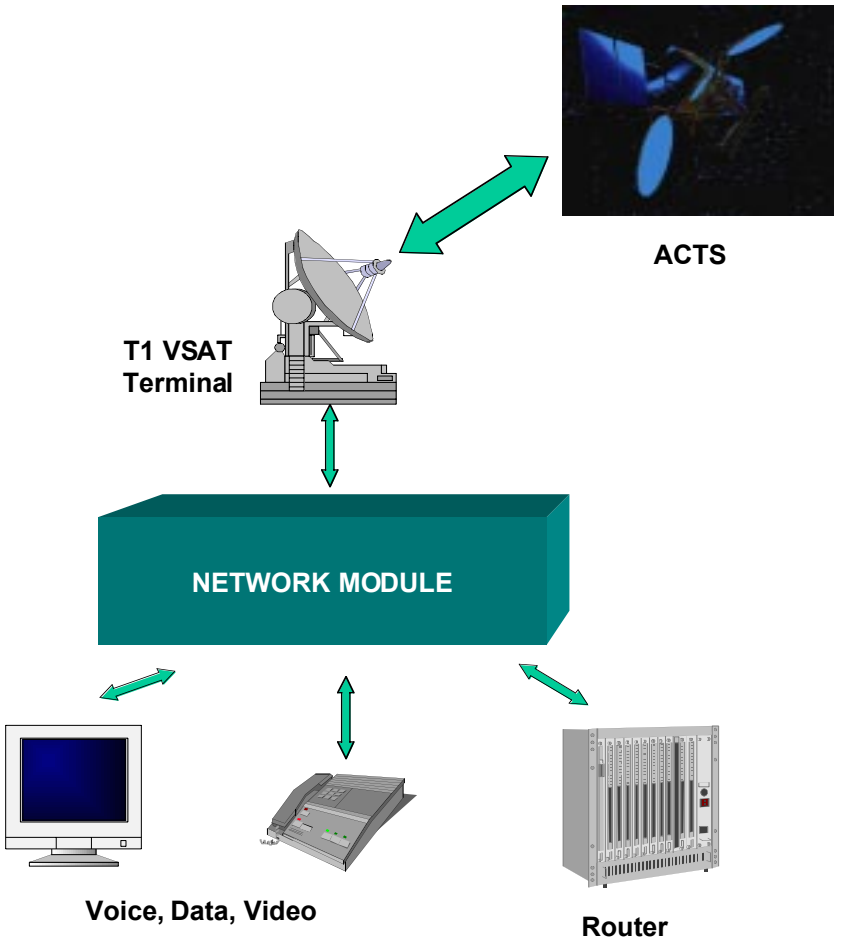
ACTS High Speed VSAT Network Module Demonstration



Features

- Can achieve line rates ranging from multiple T1's to OC-3 (155Mb/s) using COTS ATM cell concentrator
- Multiple interface modules to support commercial protocol standards

Applications

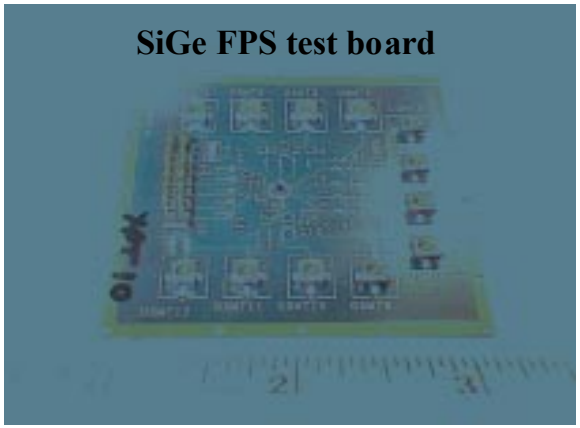
- ATM and TCP/IP over satellite
- Telemedicine
- High speed Internet
- LAN to ATM networks

Accomplishments

- Completed demonstration of ATM over ACTS satellite (64 kbps up to 24 Mbps)

SiGe Fast Packet Switch

- Develop a silicon germanium (SiGe) based Fast Packet Switch (FPS) technology for NASA and commercial communications applications that will:
  - Enable increase in satellite capacity by 10x - 100x
  - Maximize Quality of Service (QoS)
  - Be fully interoperable with terrestrial systems
- SiGe technology enables higher speeds, lower power, better performance at lower cost than GaAs
- Team of NASA Glenn, Sierra Monolithics, IBM, Nortel, Stanford University



State-of-the-art	SiGe FPS Goals	Improvement
2 Gbps/port	10-16 Gbps/port	Factor of 5-8 times
32 Gbps total throughput	160- 400 Gbps throughput	Factor of 5-16 improvement
~ 10 W power consumption	~ 5 Watts	Close to 100% improvement

6D RF Communications Module

Richard R. Kunath

Presented By:
Charles A. Raquet

Glenn Research Center

RF Communications Module

Center: GRC
Funding Enterprise: Code M/SOMO
UPN-5: 315-90, 632-50

POC: R. Kunath
Phone: 216.433.3490
email: rkunath@grc.nasa.gov

Date: 3/30/99
NTIDB Record#: 1880, 1882, 1884, 9453, 9454, 9455
Tech Prog Element: 6D

Current TRL#: 3

Planned TRL#: 6

DESCRIPTION:

- Module includes all of the hardware necessary to establish the physical layer of the communications link between a NASA user satellite and the commercial communications satellite infrastructure.
- Within the module (depending on configuration) the following elements are integrated : Modem, Up/Down Converters, Active Antennas (including SSPAs, LNAs, MPMs, and phase shifting devices) or Passive Antennas.
- A series of modules is envisioned, featuring different mature technology components and operational frequencies.

JUSTIFICATION:

- In order to leverage the significant commercial communications satellite infrastructure anticipated to be in place in the near future, NASA spacecraft must appear to these systems as typical customers (I.e. cellular telephone users, low and high data rate users, etc.). The modules developed under this task, enable that kind of functionality and bridge that gap.
- NASA spacecraft have various data rate, interactivity, and latency requirements ranging from low data rate voice communications, to multi-channel voice, video and data, to very high data rate scientific instrument data return.

RESOURCES ($K):

	FY98	FY99	FY00	FY01	FY02	FY03
Guideline				430	1830	2435

MILESTONES:

- Q2FY01 - Identify module frequency and data rate requirements from CSOC IOA technology gaps and mission needs, incorporate into RFP and release
- Q4FY01 - Award contract for baseline RF communications module
- Q4FY04 - Complete baseline RF communications module

STATUS:

- Will leverage the technology developed under the Raytheon K-band phased array contract and the SiCOM radiation hardened modem to mitigate risk and enhance performance
- Ferroelectric-based reflectarray subarray element is under development

RF Communications Module

CUSTOMER(S):

- HEDS - Helps fill specific communications technology gaps identified for the CSOC IOA, and helps enable telescience and telepresence for ISS users
- Earth Science - Provides a solution for enabling the "Sentinel Sensorweb" and the "Distributed Information System-in-the-Sky"
- Space Science - Supports near-Earth science spacecraft data return via commercial assets

MISSION RELEVANCE:

- Provides communications solution for several mission scenarios since the communications modules enables NASA mission spacecraft to leverage the commercial infrastructure available during the duration of the mission. The Space Internet strategy, of which the communications module is a critical element, seeks to reduce NASA missions operations costs by enabling NASA spacecraft to be customers of commercially provided communications.

MAPPING TO STRATEGIC ROADMAP:

Pillar 1: Reduce Cost of NASA Space Operations	1. Commercial Utilization	X	**Pillar 2:** Provide enabling data services to Enterprises	1. High Performance Comm	X
	2. Network Interoperability			2. Intelligent Syst & Autonomy	
	3. System Automation			3. Innovative Info Syst	
	4. Process Tools			4. Environm Characterization	

INTER-RELATIONSHIPS:

- The advancement in modems, microwave devices, and antenna technologies are the result of previous and current investments by the CETDP. The Raytheon phased array and the SiCOM modem developments which will be used to demonstrate the first infusion of commercially provided products in D^3 have been funded equally by Code SM and our commercial partners. A GRC radiation-hardened modem will be used by GFRC for links to TDRSS and the ground (Mike Powers). In the future, we expect joint funding from CETDP, SOMO, targeted missions, and the industry.

IMPACT OF CANCELLATION or DELAY :

- Because NASA is not considered to be a high volume customer by commercial industry, to date there has been little or no planning by the industry to include links with NASA LEO spacecraft in their constellation system designs. Consequently, NASA must invest in technology development that enables its spacecraft to appear to look like any other commercial user for which the commercial infrastructure was designed and developed. Without funding these gap-filling technologies, NASA will continue to provide and support costly point solutions for its communications.

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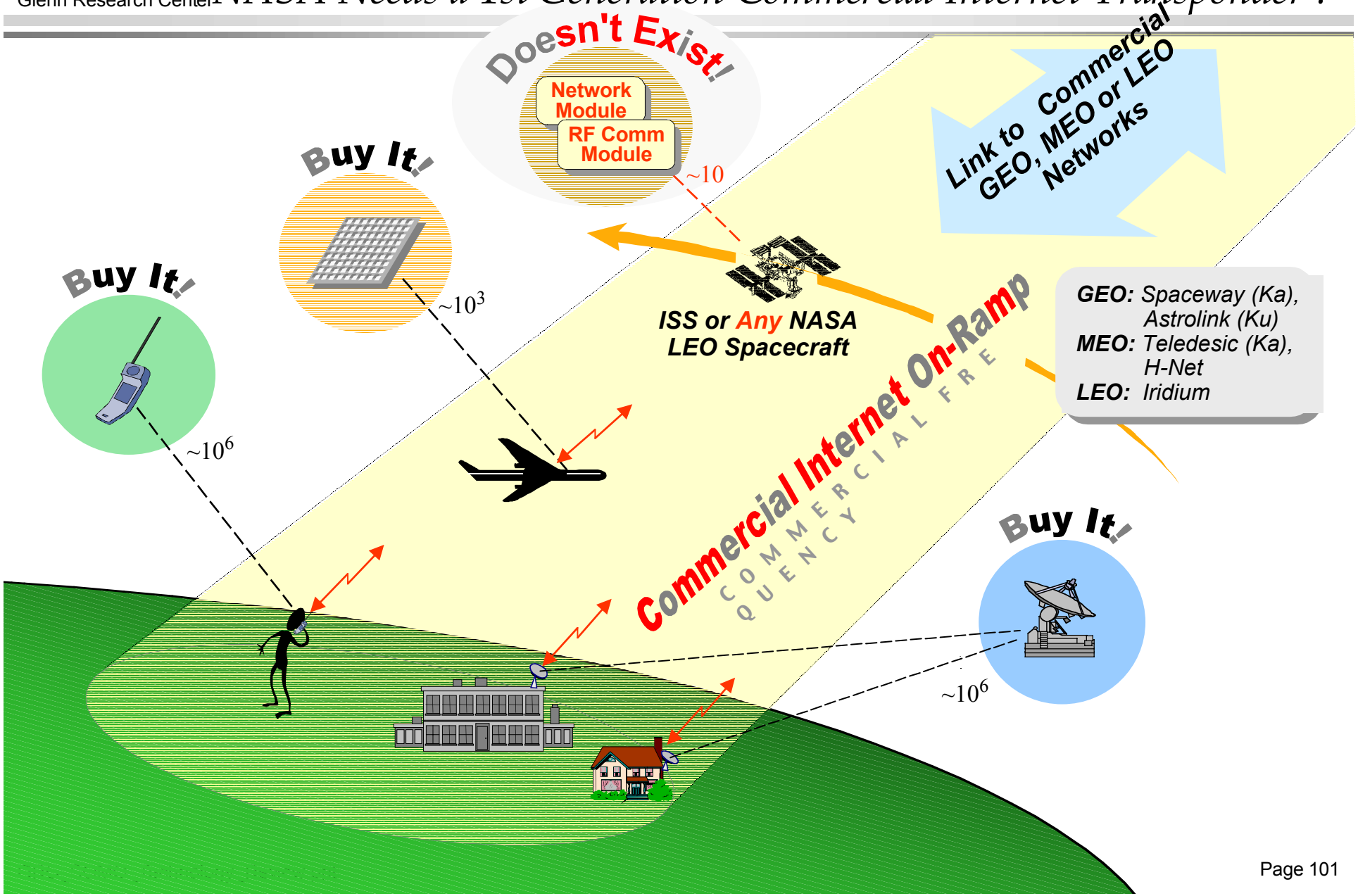
Why Develop An RF Communications Module?

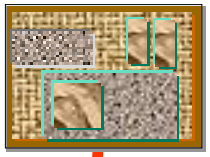
NASA Needs a 1st Generation Commercial Internet Transponder !



RF Communications Module

Known
- Commercial Frequency

TBD
- Ku or Ka-Band
- Asymmetry
- EIRP, G/T
- Tracking
- Scan Range
- Power, Mass, Space Envelopes
- Integration Level



TBD

MODEM

U/D Converters

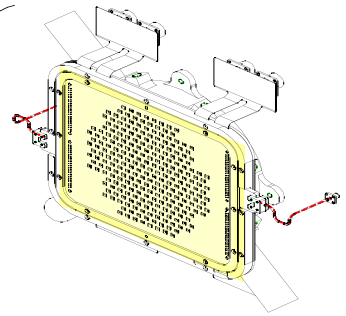
XMIT

RCV

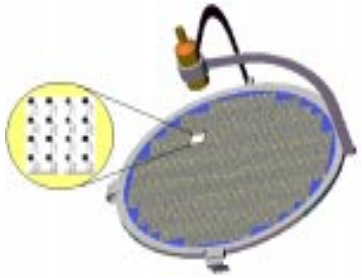
Not to Scale

SiCOM

Electronically Scanned Arrays



MMIC Array

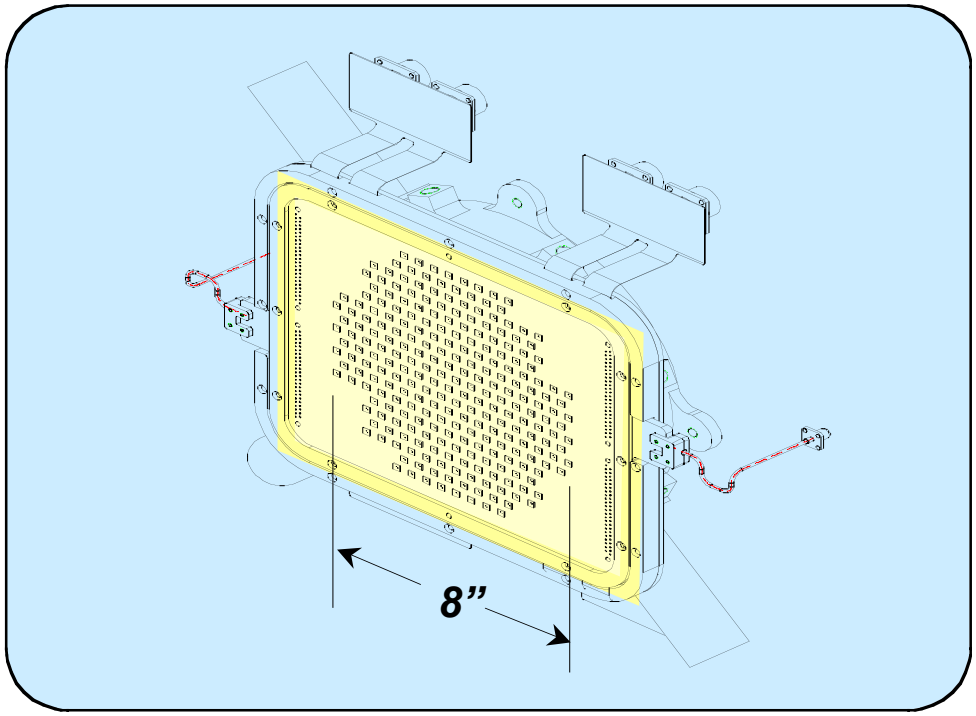


Reflectarray

Glenn Research Center

19 GHz Multibeam MMIC Transmit Phased Array Antenna

Raytheon



Characteristics:

- *Wide angle electronic scanning for LEO applications*
- *Two independently steered beams*
- *35 dbW EIRP at edge of scan (42º)*
- *Compact, tile package*
- *Designed for ease of manufacture, low cost*

Cooperative Agreement

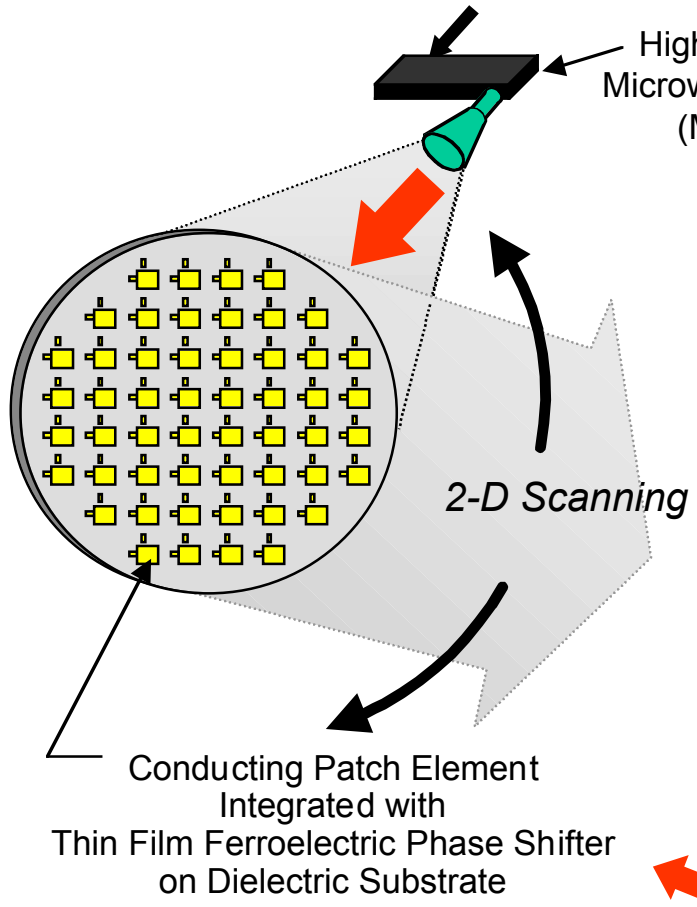
established between GRC and Raytheon:

- *Develop state-of-art K-band electronically steered MMIC array vital to both NASA and Raytheon interests*
- *Commercial frequency: 18.8-19.3 GHz*
- *50/50 cost sharing of $6.1M program*
- *High gain - Supports 622 Mbps downlink per beam at ~10^{-12} BER from Shuttle (290 km altitude) to 1.8 m tracking Earth terminal*
- *October 1999 planned completion*

CETDP Product

Reflectarray Concept

- ***Space-fed array combining the best attributes of a parabolic reflector [efficiency] and a direct radiating array [vibration-less electronic scanning]***



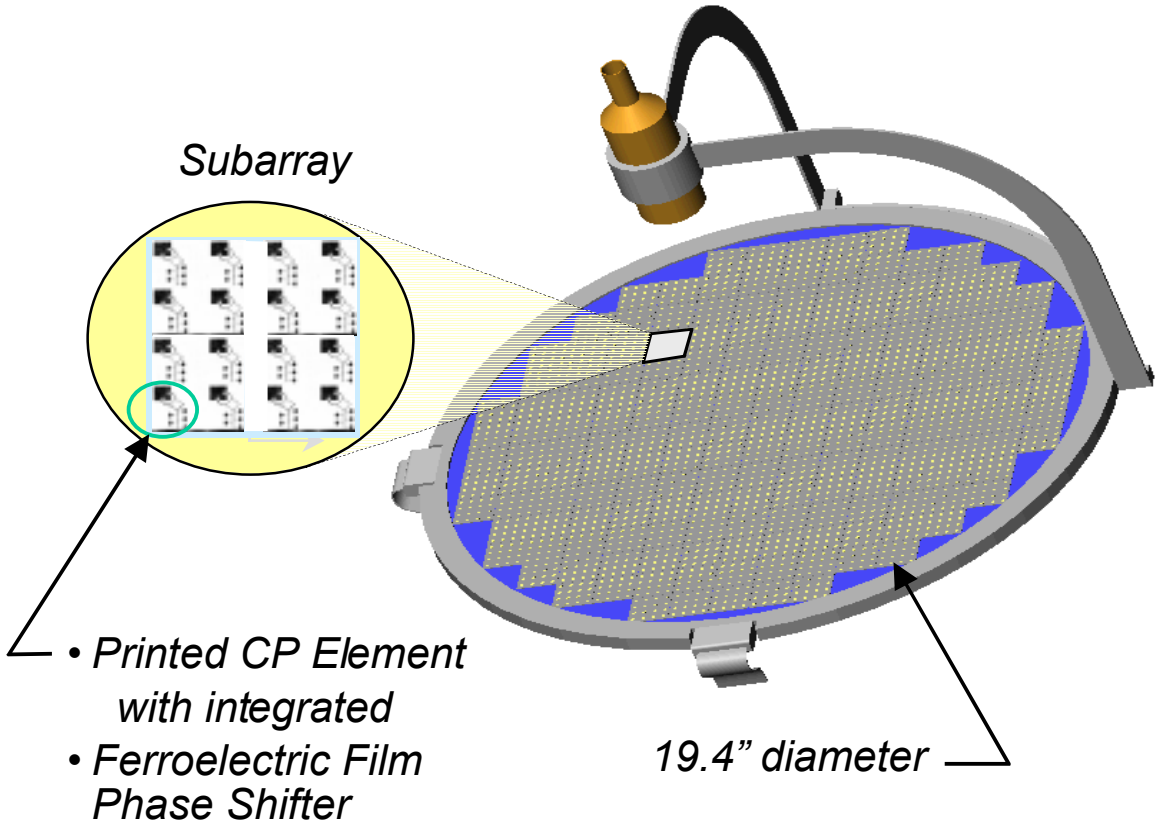
CETDP Product

FEATURES

- *Electronic steering - beam direction controlled by phase shifter bias voltages*
- *Lithographic implementation offers potential for larger aperture / gain and lower cost*
- *Single high efficiency amplifier replaces distributed amplifiers and RF manifold of MMIC array*

Patent Pending

Reflectarray Prototype

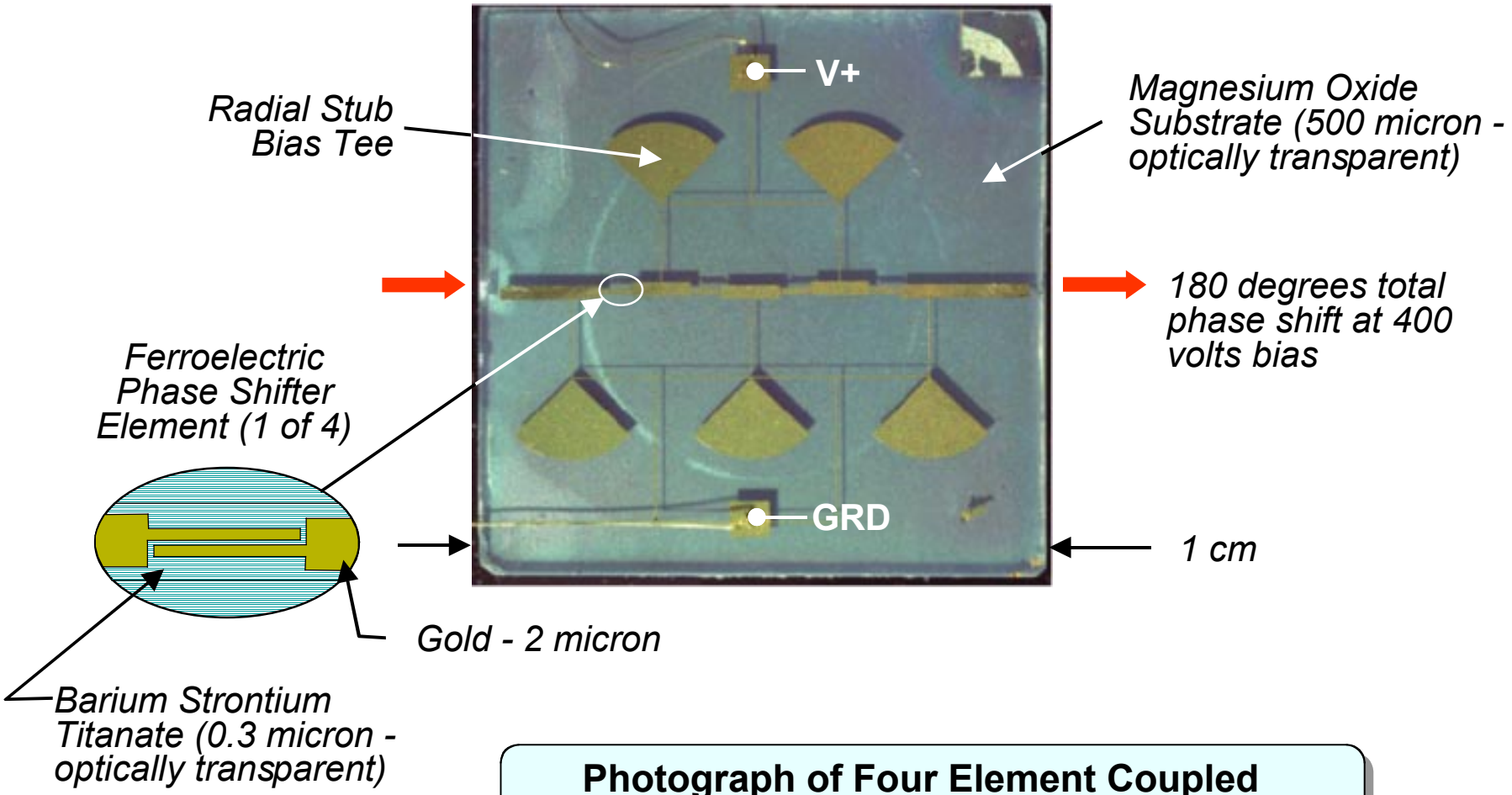


Characteristics

- 2832 elements - 176 16-element subarrays
- 3 dB insertion loss per phase shifter
- 39 dBi gain at 19 GHz

CETDP Product

Ferroelectric Phase Shifter



Photograph of Four Element Coupled Microstripline Phase Shifter

CETDP Product

6E Integrated Space Internet System Demonstrations

Phillip E. Paulsen

Glenn Research Center

Integrated Space Internet System Demos

Center: GRC
Funding Enterprise: Code M / SOMO
UPN-5: TBD
POC: P. Paulsen
Phone: 216.433.6507
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Date: 3/30/1999
NTIDB Record #: N/A
Tech Prog Element #: 6E

Current TRL: 6
Planned TRL: 7

DESCRIPTION:

- Flight testing of integrated space internet communications system
  - Includes router, network module, and RF module
  - Complete systems level qualification and integration with space flight system (STS, ISS, Spacehab, Hitchhiker,…)
  - Post-flight evaluation and system certification for flight

JUSTIFICATION:

- The development of a flight proven space internet comm system (which currently does not exist) will enable NASA's space assets to act as a "Node on the Internet"
- A flight proven space internet system is an essential part of the current IOA architecture (which assumes that they will be developed)
- Once operational, a flight proven space internet comm system will enable researchers to remotely access and control their space-based experiments, eliminating the "Person in the Loop" currently needed to physically connect experiments and comm systems

RESOURCES ($K):

	FY98	FY99	FY00	FY01	FY02	FY03
Required	N/A	N/A		125	425	1215

MILESTONES:

- Q1 FY00 - Authority to proceed, identification of flight opportunities
- Q4 FY03 - PDR & CDR, integration effort complete
- Q4 FY04 - Flight testing and post flight evaluation

STATUS:

- The flight portion of the project is highly conceptual at this time. As each of the module designs is refined and integrated with the others, further definition of the flight testing will be performed.

Integrated Space Internet System Demos

CUSTOMER(S):

- Once the IOA has been fully implemented, it is anticipated that all NASA missions will be required to use a flight proven space internet comm system for access and control of their experiments. GRC has been in communication with members from each of the following NASA Enterprises to ensure that their requirements are fully incorporated in the final design of router products:
  - Space Science
  - Mission to Planet Earth
  - Human Exploration and Development of Space
  - Aeronautics and Space Transportation Technology

MISSION RELEVANCE:

- Once fully implemented, the IOA will fundamentally change the way that NASA mission operations is conducted. It is anticipated that the following SOMO customers will be affected first:
  - STS
  - ISS
  - GSFC small missions (SMEX) & the earth observing missions

MAPPING TO STRATEGIC ROADMAP:

Pillar 1: Reduce Cost of NASA Space Operations	1. Commercial Utilization	X	**Pillar 2:** Provide enabling data services to Enterprises	1. High Performance Comm	X
	2. Network Interoperability	X		2. Intelligent Syst & Autonomy	X
	3. System Automation			3. Innovative Info Syst	X
	4. Process Tools			4. Environm Characterization	

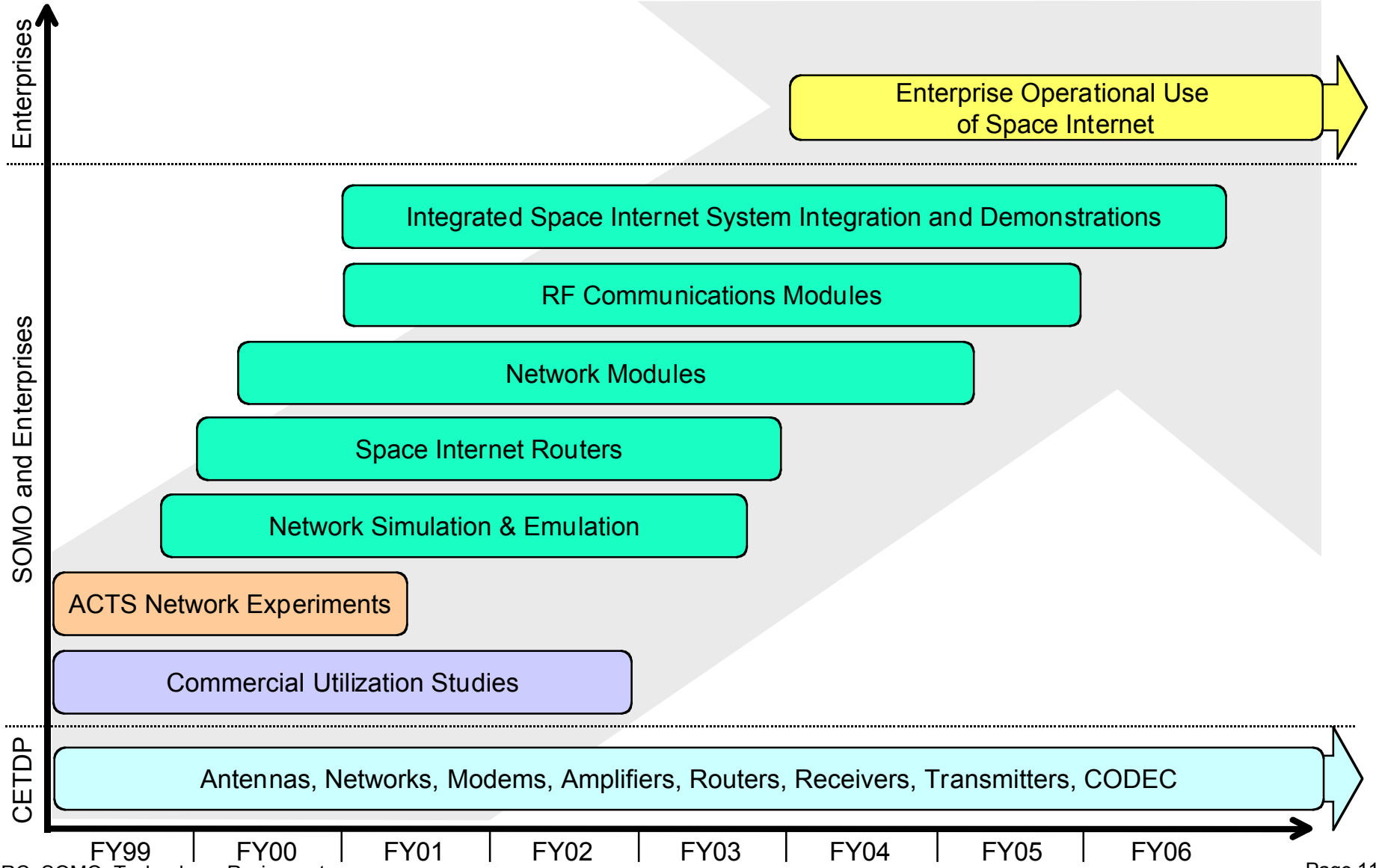
INTER-RELATIONSHIPS:

- Code SM is currently funding the development of protocols for use in a space-based internet
- Close coordination with spacecraft managers and manufacturers will be essential to adequately define all requirements and build successful, cost-effective, IOA compliant communication systems

IMPACT OF CANCELLATION or DELAY :

- The IOA as written can never be fully implemented without flight proven space internet communications hardware

Space Internet Technology Insertion Roadmap



Concluding Remarks & Discussion